TITLE OF THE INVENTION

CO_2 INCUBATOR

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to a CO_2 incubator for incubating cells sampled from blood or a specimen by controlling a temperature, a humidity and an atmosphere of the cells.

Description of the Related Art

In recent years, with the development of fields regarding biotechnology and regeneration medicine, works for incubating cells by using an incubator tend to increase. To accelerate the incubation of the cells, it is necessary to regulate an incubation space suitable for each cell, and heretofore, some incubators have been developed which control a temperature, a humidity and an atmosphere in the incubation space.

Particularly, to incubate the cells which requires severe concentration conditions of a CO_2 (carbon dioxide) gas, a CO_2 incubator is used as a device for controlling the CO_2 gas concentration in the incubation space in addition to a device for controlling the temperature and the humidity (e.g., refer to Patent Document 1 and Patent Document 2).

[Patent Document 1]

Official gazette of Japanese Patent Application Laid-Open No. 9-23877

[Patent Document 2]

Official gazette of Japanese Patent Application Laid-Open No. 2000-93156

However, in the case of the conventional CO_2 incubator, when a door is automatically or manually opened and closed, CO_2 leaks to the outside from a storeroom of the CO_2 incubator and the CO_2 gas concentration in the storeroom fluctuates. Moreover, when the door is frequently opened and closed to put in or take out the incubation cells, the CO_2 gas concentration in the storeroom fluctuates before the CO_2 gas concentration in the storeroom returns to its predetermined concentration. Therefore, there is a problem that the state of the incubation space of the cells becomes unstable, which adversely affects the growth of the cells.

For the solution of the problem, in the case of the conventional CO_2 incubator, a CO_2 concentration sensor is disposed in the storeroom for the fluctuation of the CO_2 gas concentration. In consequence, when the CO_2 concentration is recognized to be lower than a set value in accordance with an output of the sensor, a switching valve for supplying the CO_2 gas into the storeroom is opened, and when the CO_2 concentration reaches the set value, the switching valve is closed.

In this case, the above conventional CO_2 gas concentration sensor has a poor concentration detecting performance, and hence, a problem that the accuracy of the detected concentration is low, and moreover, a long time is

required to detect the concentration. In addition, an airtight structure is used to reduce a gas consumption, and if overshoot occurs, it takes a long time to return to a predetermined value. Therefore, there is no way other than an operation of decreasing a gas injection quantity to decelerate recovery. The above control is due to an imperfect performance of the sensor. In any case, when the switching valve for supplying the CO_2 gas is controlled in accordance with the output of the CO_2 gas concentration sensor as in the conventional case, a problem occurs that the actual CO_2 gas concentration overshoots or undershoots to the preset CO_2 gas concentration.

Therefore, there is a problem that it is difficult to realize the strict CO_2 gas concentration and it is impossible to sufficiently regulate the cell incubation space.

SUMMARY OF THE INVENTION

Therefore, the present invention has been developed to solve the above conventional technical problems, and an object of the present invention is to provide a CO_2 incubator capable of accurately controlling a CO_2 gas concentration in an incubation space and quickly coping with a sudden change of the CO_2 gas concentration in the incubation space.

A first aspect of the present invention is directed to a CO_2 incubator for incubating a culture medium accommodated in an incubation space defined in a storeroom, the CO_2 incubator comprising CO_2 gas concentration detection

means for detecting a CO_2 concentration in the incubation space, CO_2 gas concentration setting means for setting the CO_2 gas concentration in the incubation space, CO_2 gas supply means for supplying a CO_2 gas into the incubation space, and control means for controlling the CO_2 gas supply means, wherein the control means executes an operation of proportion, proportion and integration, or proportion and integration and differentiation on the basis of a deviation between the CO_2 gas concentration in the incubation space and a set CO_2 gas concentration value by the CO_2 gas concentration detection means and the CO_2 gas concentration setting means to calculate a CO_2 gas supply time per unit time to the incubation space and a stop time, and supplies a CO_2 gas to the incubation space from the CO_2 gas supply means in accordance with the calculated supply time and stop time.

According to the thus constituted first aspect of the present invention, overshoot and undershoot of the CO_2 gas concentration can be previously avoided by the above control means, whereby the CO_2 gas concentration can be accurately controlled.

In consequence, even if the CO_2 gas concentration in the incubation space is extremely changed by opening or closing a door, the CO_2 gas can be quickly supplied to the incubation space in accordance with the changed CO_2 gas concentration in the incubation space, whereby the stable incubation space can be provided.

A second aspect of the present invention is directed

to the CO_2 incubator according to the first aspect of the present invention, wherein the CO_2 gas concentration detection means is constituted of a CO_2 sensor using infrared rays.

According to the second aspect of the present invention, it is possible to further quickly and accurately detect the CO_2 gas concentration in the incubation space, because the CO_2 gas detection means is constituted of a CO_2 sensor using infrared rays in the first aspect of the present invention.

A third aspect of the present invention is directed to the CO_2 incubator according to the first aspect or the second aspect of the present invention, wherein a plurality of incubation spaces are disposed and the control means selects the gas in any incubation space, detects the CO_2 gas concentration of the selected gas by the CO_2 gas concentration detection means, and controls the supply of the CO_2 gas to each incubation space in accordance with the detected CO_2 gas concentration.

According to the third aspect of the present invention, a plurality of incubation spaces are disposed and the control means selects the gas in any incubation space, detects the CO_2 gas concentration of the selected gas by the CO_2 gas concentration detection means, and controls the supply of the CO_2 gas to each incubation space in accordance with the detected CO_2 gas concentration in the first aspect or the second aspect of the present invention. Therefore,

the CO_2 gas concentration can be controlled for each incubation space.

Moreover, since the CO_2 gas concentration detection means and the control means control the CO_2 gas concentrations in the respective incubation spaces by using common means, it is possible to avoid a fluctuation of the CO_2 gas concentration in each incubation space caused by an error of the CO_2 gas concentration detection means or the control means, as compared with a case where the CO_2 gas concentrations in the respective incubation spaces are controlled by the plurality of CO_2 incubators.

A fourth aspect of the present invention is directed to the CO_2 incubator according to the third aspect of the present invention, wherein the control means displays the CO_2 gas concentration detected in each incubation space in the third aspect of the present invention.

According to the fourth aspect of the present invention, because the control means displays the CO_2 gas concentration detected in each incubation space in the third aspect of the present invention, the CO_2 gas concentration in each incubation space can be easily visually confirmed, whereby convenience is further improved.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of a CO_2 incubator of the present invention showing the flow of air; and

FIG. 2 is a schematic block diagram of a CO_2 incubator of another embodiment showing the flow of air.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Next, an embodiment of the present invention will be described below in detail by referring to the accompanying drawings. FIG. 1 shows a schematic block diagram of a CO_2 incubator 1 of the present invention showing the flow of air. In the case of the CO_2 incubator 1 of the present invention, a body 2 is constituted of an adiabatic housing having an opening (not shown) on, for example, one face, and an incubation space S is defined in the body 2 (in the storeroom). Moreover, the body 2 is provided with a door, not shown, for closing the opening which can be opened and closed.

The body 2 is provided with an air-agitating blower 3 for agitating the air in the incubation space S to uniform the state of the air. It is to be noted that the air-agitating blower 3 is operated by a blower motor 3A, and the blower motor 3A is controlled by a controller not shown.

Moreover, the body 2 is connected to a measurement air sampling tube 4 so as to communicate with the inside of the incubation space S, and the measurement air sampling tube 4 is connected to a CO_2 gas concentration sensor 6 as CO_2 gas concentration detection means for detecting the CO_2 gas concentration in the incubation space S through a pump 5. The CO_2 gas concentration sensor 6 used in this embodiment

may be a CO_2 sensor using infrared rays.

This CO_2 sensor using the infrared rays calculates the CO_2 gas concentration by using a principle that the CO_2 gas absorbs a wavelength of 4.3 μm. That is to say, the CO_2 sensor measures a wavelength absorbing degree, converts the measured data into an electrical signal, and calculates the CO_2 gas concentration. Moreover, this CO_2 sensor (CO_2 gas concentration sensor 6) may be connected to a CO_2 gas controller 11 which will be described later in detail.

Furthermore, the CO_2 gas concentration sensor 6 is connected to a measurement air return tube 7 whose one end communicates with the inside of incubation space S of the body 2. In consequence, when the pump 5 is operated, the air taken by the CO_2 gas concentration sensor 6 through the measurement air sampling tube 4 from the inside of the incubation space S is returned to the inside of the incubation space S through the measurement air return tube 7.

On the other hand, the body 2 is connected to a CO_2 gas supply tube 8 so as to communicate with the inside of the incubation space S, and the CO_2 gas supply tube 8 is connected to a CO_2 gas cylinder 10 through an electromagnetic switching valve 9 as CO_2 gas supply means. In this CO_2 gas cylinder 10, the CO_2 gas having a purity of 95% or more may be contained.

Here, the CO_2 gas controller 11 will be described below. The input side of the CO_2 gas controller 11 is connected to the CO_2 gas concentration sensor 6 and a control

panel 12, and the output side of the CO_2 gas controller 11 is connected to the electromagnetic switching valve 9.

The control panel 12 is provided with CO_2 gas concentration setting means for setting the CO_2 gas concentration in the incubation space S, and for example, the control panel 12 is disposed in front of the body 2. Moreover, the control panel 12 may be provided with a display portion 12A for displaying the actually detected CO_2 gas concentration in the incubation space S and the set CO_2 gas concentration.

The CO_2 gas controller 11 controls the electromagnetic switching valve 9 as CO_2 supply means in accordance with the CO_2 gas concentration sensor 6 and control panel 12 and includes a PID-operation processing section 11A. The PID-operation processing section 11A executes operations of proportion (P), integration (I) and differentiation (D) on the basis of a deviation e between a CO_2 gas concentration in the incubation space S detected by the CO_2 gas concentration sensor 6 and a set CO_2 gas concentration value which is optionally set by the control panel 12. That is, the PID-operation processing section 11A performs a proportional operation for calculating a control amount so as to reduce the deviation e in proportion to the deviation e between the CO_2 gas concentration detected by the CO_2 gas concentration sensor 6 and a set CO_2 gas concentration value, an integral operation for calculating a control amount for reducing an integrated value of the

deviation e, and a differential operation for calculating a control amount for reducing a gradient (differentiated value) of a change of the deviation. Next, these control amounts are added together to calculate a CO_2 gas supply time per unit time (every certain cycle of, e.g., 3 seconds) of the electromagnetic switching valve 9 and a stop time in accordance with the control amounts.

Then, the CO_2 gas controller 11 controls the electromagnetic switching valve 9 as CO_2 gas supply means in accordance with the CO_2 gas supply time and the stop time calculated in accordance with the PID control and controls the supply of the CO_2 gas to the incubation space S from the CO_2 gas cylinder 10. In the case of this embodiment, operation processings of proportion, integration, and differentiation are performed in accordance with a deviation between a detected CO_2 gas concentration and a set CO_2 gas concentration set value to calculate a CO_2 gas supply time and a stop time. Moreover, it is allowed to calculate the CO_2 gas supply time and the stop time by executing operations of only proportion or operations of only proportion and integration in accordance with the deviation.

Operations of a CO_2 incubator will be described below in accordance with the above configuration. First, a user operates the control panel 12 to set the CO_2 gas concentration in the incubation space S. In this case, some air in the incubation space S is attracted into the measurement air sampling tube 4 by operating the pump 5 and

captured into the CO_2 gas concentration sensor 6. Thereafter, the air used for measurement is returned to the incubation space S through the measurement air return tube 7.

In this case, the CO_2 gas concentration sensor 6 measures the absorbance of a wavelength of 4.3 μm by infrared rays to calculate a CO_2 gas concentration. The CO_2 gas controller 11 executes the above-described PID operation processing in accordance with the calculated CO_2 gas concentration and the CO_2 gas concentration set value set as described above. Moreover, the controller 11 calculates the CO_2 gas supply time and the stop time per unit time in accordance with the PID operation processing and controls the electromagnetic switching valve 9 in accordance with the supply time and the stop time. Then, the controller 11 supplies the CO_2 gas into the incubation space S through the CO_2 gas supply tube 8 from the CO_2 gas cylinder 10. The CO_2 gas supply quantity increases when the rate of the supply time in the above three secconds (supply time + stop time) rises but decreases when the rate lowers. The above operation is calculated every three sec to perform a fine control.

Thereby, it is possible to prevent overshoot and undershoot in the control of a CO_2 gas concentration and accurately control the CO_2 gas concentration in the incubation space S. Therefore, even if the CO_2 gas concentration in the incubation space S is extremely changed by opening or closing the door, it is possible to quickly

supply the CO_2 gas into the incubation space S in accordance with a changed CO_2 gas concentration in the incubation space S and stably supply the incubation space S.

Particularly, because the CO_2 gas concentration sensor 6 of this embodiment for detecting the CO_2 gas concentration in the incubation space S is constituted of a CO_2 sensor using infrared rays, it is possible to further quickly and accurately detect the CO_2 gas concentration in the incubation space S.

Then, another embodiment of the present invention is described below by referring to FIG. 2. FIG. 2 shows a schematic block diagram of a CO_2 incubator 20 of another embodiment of the present invention showing the flow of air. It is to be noted that the members having the same symbols as in FIG. 1 have similar effects.

In the case of the CO_2 incubator 20 of this embodiment, a body 22 is constituted of an adiabatic housing having an opening (not illustrated) on one face the same as the case of the above embodiment. Moreover, a partition wall 22 is formed in the inside (storeroom) of the body 22 and incubation spaces 1S and 2S divided by the partition wall 21 are also formed. Furthermore, the body 22 is provided with a not-illustrated door for blocking the incubation spaces 1S and 2S respectively so that the opening can be opened or closed.

On the other hand, the body 22 is connected with measurement air sampling tubes 4A and 4B so as to communicate

with insides of the incubation spaces S1 and S2, respectively, and these measurement air sampling tubes 4A and 4B are connected to a measurement air sampling tube 4 through a three-way tube 23. The measurement air sampling tube 4 connected to a CO_2 gas concentration sensor 6 as CO_2 gas concentration detection means for detecting the CO_2 gas concentration in the incubation space S1 of S2 through a pump 5. Also in the case of this embodiment, the CO_2 gas concentration sensor 6 may be a CO_2 sensor using infrared rays. Moreover, the CO_2 gas concentration sensor 6 may be connected to a CO_2 gas controller 25 which will be described later in detail.

Furthermore, the CO_2 gas concentration sensor 6 is connected to a measurement air return tube 7, and the other end of the measurement air return tube 7 is connected to measurement air return tubes 7A and 7B communicating with the incubation spaces S1 and S2 through a three-way tube 24. In consequence, when the pump 5 is operated, the air selectively captured into the measurement air sampling tube 4 from the incubation space S1 or S2 is returned to the original incubation space S1 or S2 through the CO_2 gas concentration sensor 6 and measurement air return tube 7.

Furthermore, the body 22 is connected to CO_2 gas supply tubes 8A and 8B so as to communicate with the insides of the incubation spaces S1 and S2, and the CO_2 gas supply tubes 8A and 8B are connected to a CO_2 gas cylinder 10 through electromagnetic switching valves 9A and 9B as CO_2 gas

supply means.

The CO_2 gas controller 25 will be described below. The input side of the CO_2 gas controller 25 is connected to the CO_2 gas concentration sensor 6 and control panel 12, and the output side of the CO_2 gas controller 11 is connected to the three-way valves 23 and 24 and the electromagnetic switching valves 9A and 9B.

The control panel 12 serves as CO_2 gas concentration setting means for setting the CO_2 gas concentration in each of the incubation spaces S1 and S2 the same as the case of the above embodiment and is set to, for example, the front of the body 2. Furthermore, the control panel 12 may be provided with display portions 12A and 12B for displaying an actually detected CO_2 gas concentration in each of the incubation spaces S1 and S2 and a set CO_2 gas concentration.

The CO_2 gas controller 25 includes a PID-operation processing section 25A therein as in the CO_2 gas controller 11 of the above embodiment, and controls the electromagnetic switching valve 9A or 9B as the CO_2 supply means by the CO_2 gas concentration sensor 6 for detecting the CO_2 gas concentration of the air in selected one of the incubation spaces S1 and S2 and the control panel 12 as the CO_2 gas concentration setting means. It is to be noted that the PID-operation processing section 25A may have the same constitution as the PID-operation processing section 11A of the above embodiment.

Operations of the CO_2 incubator 20 of the present

invention will be described below in accordance with the above configuration. First, a user operates the control panel 12 to set the CO_2 gas concentration in the incubation space S1 and/or S2. The CO_2 gas concentration controller 25 selects either of the incubation spaces S1 and S2 and opens one of the three-way valves 23 and 24 and closes the other so as to make it possible to sample the air in the selected incubation space S1 or S2.

Thereafter, some of the air in the selected incubation space S1 or S2 is attracted into the measurement air sampling tube 4 by operating the pump 5 and captured into the CO_2 gas concentration sensor 6. Then, the air used for measurement is returned to the original incubation space S1 or S2 through the measurement air return tube 7.

In this case, the CO_2 gas concentration sensor 6 measures the absorbance of a wavelength of 4.3 μm with infrared rays and calculates a CO_2 gas concentration. Then, the CO_2 gas controller 25 performs the PID control the same as the case of the above embodiment in accordance with the calculated CO_2 gas concentration and a preset CO_2 gas concentration set value, calculates the CO_2 gas supply time and the stop time for each based unit time, and controls the electromagnetic switching valve 9A or 9B corresponding to the selected incubation space S1 or S2 in accordance with the calculated supply time and stop time. Moreover, the controller 25 supplies the CO_2 gas to the incubation space S1 or S2 from the CO_2 gas cylinder 10 through the CO_2 gas supply

tube 8A or 8B.

According to the above configuration, it is possible to avoid overshoot or undershoot through the control of the CO_2 gas concentration in each of the incubation spaces S1 and S2 and accurately control the CO_2 gas concentration in each of the incubation spaces S1 and S2. Therefore, even if the CO_2 gas concentration in the incubation spaces S1 and S2 is extremely changed by opening or closing the door, it is possible to quickly supply the CO_2 gas to the incubation spaces S1 and S2 in accordance with the changed CO_2 gas concentration in each of the incubation spaces S1 and S2 and provide stable incubation spaces S1 and S2.

Moreover, even in the case of the CO_2 incubator 20 in which a plurality of incubation spaces are defined as in this embodiment, the CO_2 gas concentration in each of the incubation spaces S1 and S2 can be controlled by using the common pump 5, the CO_2 gas concentration sensor 6 and the CO_2 gas controller 25, whereby a plurality of types of incubation spaces can be defined in one CO_2 incubator 20.

Particularly in the above case, because a CO_2 gas concentration can be controlled by using the common CO_2 gas concentration sensor 6 and CO_2 gas controller 25, it is possible to avoid the fluctuation of the CO_2 gas concentration in a incubation space caused by an error of CO_2 gas concentration detection means or control means compared to the case of controlling the CO_2 gas concentration in each of the incubation spaces S1 and S2 by a plurality of CO_2

incubators.

Moreover, because the control panel 12 of this embodiment is provided with the display portions 12A and 12B for displaying the CO_2 gas concentrations detected in the respective incubation spaces S1 and S2, the CO_2 gas concentrations in the respective incubation spaces S1 and S2 can be easily visually confirmed, whereby convenience is further improved.

With regard to the CO_2 incubators 1 and 20 of the above embodiments, reference has been made to the CO_2 gas concentration control alone in the incubation spaces S1 and S2. However, it is also allowed to use an incubator making it possible to control an environment required to incubate cells such as temperature control and humidity control in each of the incubation spaces S1 and S2.

As described above, according to the present invention, a CO_2 incubator for incubating a culture medium accommodated in an incubation space defined in a storeroom comprises CO_2 gas concentration detection means for detecting a CO_2 concentration in the incubation space, CO_2 gas concentration setting means for setting the CO_2 concentration in the incubation space, CO_2 gas supply means for supplying the CO_2 gas into the incubation space, and control means for controlling the CO_2 gas supply means, wherein the control means executes an operation of proportion, proportion and integration, or proportion and integration and differentiation on the basis of a deviation between the CO_2

gas concentration in the incubation space and a set CO_2 gas concentration value by the CO_2 gas concentration detection means and the CO_2 gas concentration setting means to calculate a CO_2 gas supply time per unit time to the incubation space and a stop time, and supplies the CO_2 gas to the incubation space from the CO_2 gas supply means in accordance with the calculated supply time and stop time. Accordingly, overshoot and undershoot of the CO_2 gas concentration can be previously avoided, whereby the CO_2 gas concentration can be accurately controlled.

Consequently, even if the CO_2 gas concentration in the incubation space is extremely changed, e.g., by opening or closing a door, the CO_2 gas can be quickly supplied to the incubation space in accordance with the changed CO_2 gas concentration in the incubation space, whereby the stable incubation space can be provided.

According to the invention of claim 2, the CO_2 gas concentration detection means is constituted of a CO_2 sensor using infrared rays in the invention of claim 1, and hence, the CO_2 gas concentration in the incubation space can be further quickly and accurately detected.

According to the invention of claim 3, a plurality of incubation spaces are disposed, and the control means selects any gas in any incubation space, detects the CO_2 gas concentration of the selected gas by the CO_2 gas concentration detection means, and controls the supply of the CO_2 gas to each incubation space in accordance with the

detected CO_2 gas concentration. Accordingly, it is possible to control the CO_2 gas concentration in each incubation space.

Moreover, because the CO_2 gas concentration detection means and the control means control the CO_2 gas concentration in each incubation space by using common means, it is possible to previously avoid the fluctuation of the CO_2 gas concentration in an incubation space caused by an error of the CO_2 gas concentration detection means or the control means, as compared with the case of controlling CO_2 gas concentrations in the incubation spaces by a plurality of CO_2 incubators.

According to the invention of claim 4, the control means displays the CO_2 gas concentration detected in each incubation space in the invention of claim 3, and hence, the CO_2 gas concentration in each incubation space can be easily visually confirmed, whereby convenience is further improved.